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TRACER EXPERIMENTS FOR DISPERSION MODELLING IN RIVER DOURO WATER QUALITY MANAGEMENT

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ABSTRACT

Parameters estimation for in situ dispersion river water behaviour characterisation, and performance evaluation of numerical models, applied to reproduce data field obtained from dye tracer experiments, were the main purposes of this research work.
A monitoring program was carried out using tracer injection to assess the environmental impact of accidental pollutant discharges in an international reach of river Douro, between Castro dam (Spain) and Miranda dam (Portugal).
This paper presents the methodology used in the tracer experiments, the concentration-time curves, describing dye tracer spread, the results of different simulation and their agreement with the measured data, and peak attenuation with dye spread travel time. Longitudinal dispersion coefficients values are estimated according to the river hydrodynamics.

KEYWORDS

Longitudinal dispersion, mathematical models, tracer experiments, river Douro, water quality.

INTRODUCTION

Judicious selection of mathematical models for application in a specific river basin management can mitigate prediction uncertainty. Therefore, operational actions, based on reliable travel times, can be established in order to efficiently protect the aquatic ecosystems.

The study area occupies an international Douro river reach located in the north-eastern region of Portugal. This river reach begins downstream of Castro reservoir (Spain), and ends at Miranda reservoir (Portugal), in a distance of approximately 13,5 km. Four sampling sites were considered, being the site 0 (downstream Castro dam) the upstream dye tracer injection point (Fig. 1).

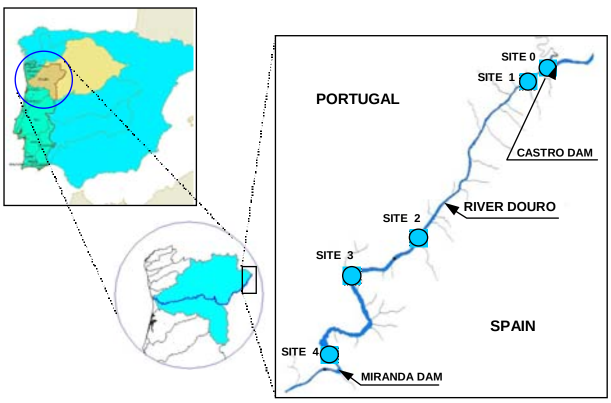

Figure 1. River Douro basin and sampling sites location

METHODS

A monitoring programme was carried out using tracer injection (rhodamine WT-20% solution) to evaluate the *in situ* dispersion river water behaviour under flow ranges from 170 to 457 m^3/s. Seven sampling campaigns in consecutive years of 1985 to 1987 were developed. Blanks were taken in all sampling points for river natural fluorescence determination. Table 1 presents the information about all tracer injections on the seven sampling campaigns made in this study. Sampling sites characteristics are presented in Figure 2.

TABLE 1 Rhodamine injection program information

Year	Program	Date	Time	River flow (m^3/s)	Water level ** (m)	Rhodamine WT mass (kg)	Sampling L	Sampling V	Sampling T
1985	1º	85-05-07/09	9:00	400	-	11.5 *	1-4	-	-
	2º	85-09-24/26	8:00	170	-	5	1-4	-	-
1986	1º	86-10-01/03	7:30	254	524	5	1-4	-	-
	2º	86-10-29/31	8:00	265	526	5	1-4	2-4	3, 4
1987	1º	87-04-08/10	10:00	457	525 - 522	5	1-4	3	2, 3
	2º	87-07-22/24	6:35	100 (?)	527 - 526	5	1-4	2	1, 2
	3º	87-11-18/20	7:30	352	525 - 524	5	1-4	3	1-3

Nota : L = longitudinal ; V = vertical ; T = transversal .

* - Rhodamine B ; ** - Miranda reservoir

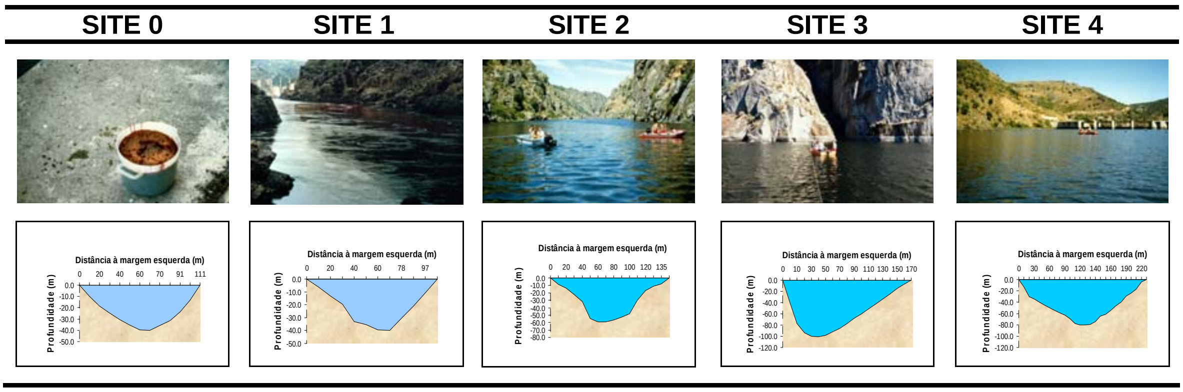

Figure 2. Sampling sites characteristics

The flow regime of this river reach is strongly influenced by the Castro reservoir discharged flows, by the water flows used in hydropower generation in Miranda dam, and by the surface water levels in Miranda reservoir (Fig. 3).

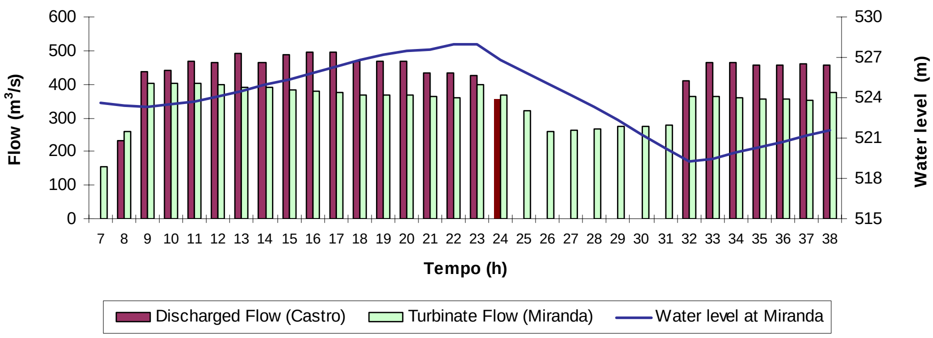

Figure 3. Flow discharges and surface water level at Miranda reservoir

DUFLOW model (ICIM, 1992) was designed to cover a large range of applications in different water systems and to assess water quality problems (Vieira *et al*., 1998). Average values of flow discharges at Castro reservoir and mass of injected rhodamine are considered as upstream boundary conditions. Surface water level at Miranda reservoir was taken as downstream boundary condition.

RESULTS

Transversal variation of the tracer concentration verified in sampling site 2 is presented in Figure 4. Similar results were obtained in the other sites allowing conclude that mixing conditions were favourable to a rapid concentration equalisation in that direction.

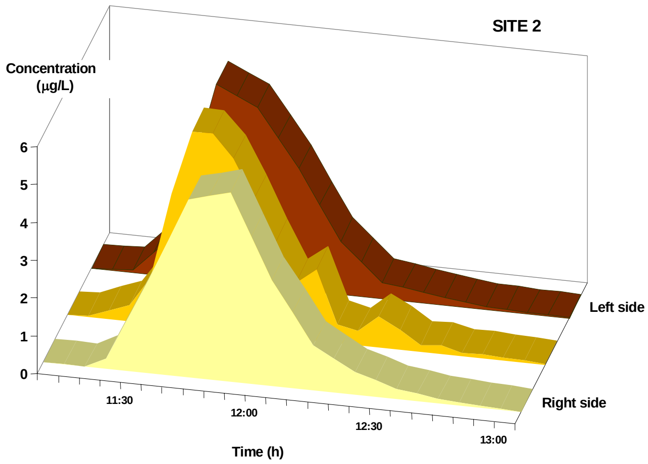

Figure 4. Transversal variation of the tracer concentration (site 2)

Model calibration procedure (Fig. 5) included the adjustment of the friction bottom value in each reach and longitudinal dispersion coefficients. The model has been validated using other sampling data (November 87), obtained under different flow regime (Fig. 6).

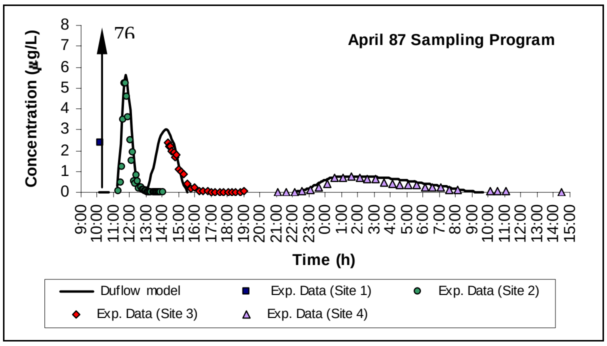

Figure. 5 Model calibration

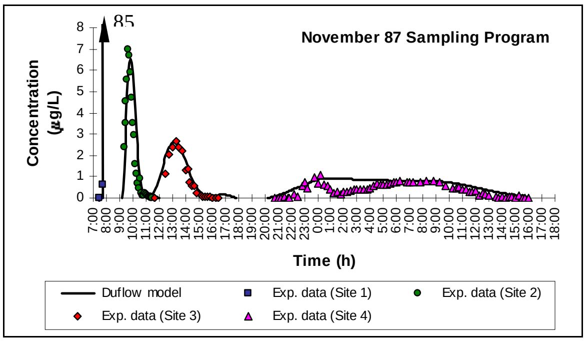

Figure 6. Model validation

It was reported that the ratio tracer peak concentration (Cp) over total mass of rhodamine injected varies with a negative power of the travel time. This exponent is a constant value (0,84 and 0,86) depending on the dispersion river characteristics (Fig. 7). Lower values were obtained in studies for other river basins (Duarte *et al*., 1999a, 1999b), in reaches without reservoirs.

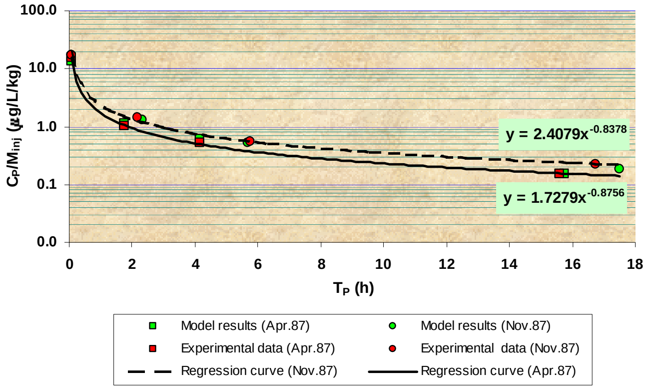

Figure 7. Peak concentration variation with dye spread travel time

Table 2 compares travel time and dispersion coefficient obtained from the model with tracer experimental data. It is apparent slight differences between experimental longitudinal dispersion coefficient values and those adopted for model calibration.

TABLE 2 Comparison between experimental data and model results

REACH	TIME TRAVEL (h)				DISPERSION COEFICIENT ($m^2.s^{-1}$)	
	APRIL 87		NOVEMBER 87		DUFLOW	
	EXPERIMENTAL	DUFLOW	EXPERIMENTAL	DUFLOW	APRIL 87	NOVEMBER 87
Site 0 - Site 1	0:05	0:05	0.06	0:05	50	45
Site 1 - Site 2	1:45	1:45	2:10	2:20	30	20
Site 2 - Site 3	4:10	4:20	5:45	5:40	5	20
Site 3 - Site 4	15:35	15:45	16:45	17:30	2	2

CONCLUSIONS

This work presents longitudinal dispersion coefficients estimation results and peak attenuation with dye spread travel time for Miranda reservoir in the international river Douro. Further developments will be done (2D-V models) in order to simulate vertical dispersion processes.

One-dimensional mathematical modelling appears to be a powerful tool to solve pollutant transport problems in river systems with longitudinal dispersion behaviour similar to the studied river Douro reservoir, even under different flow regimes. DUFLOW model results showed a good agreement with experimental data, allowing a reasonable support for impact assessment of different discharges scenarios in the river water quality. This procedure is of paramount interest in river basin management strategy for defining alarm schemes, minimising the effects from accidental pollutant spills.

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